its authority and prestige would have been very different. It is a high honour to be selected one of a small élite. It is a doubtful compliment to be included in a miscellaneous crowd, and one may not feel very proud to add the letters F.R.S.E. after one's name.

It is not too much to say that the history of the Royal Academy of Brussels for the last hundred years is the history of Belgian science and Belgian learning. Nothing is more remarkable in its activities than the universality of their range. The Academy may claim among its members men of world-wide reputation in every branch of activity. It has produced mathematicians and physicists like Quetelet and Stas; naturalists and chemists like van Beneden and Spring; jurists like Willems and Thonissen; historians like Gachard, Kurth, Cumont, and Pirenne. Looking at the record of those eminent men, Belgium is entitled to a high place amongst the smaller powers of Europe. In one important respect the Royal Academy of Belgium has set an example even to larger and more ancient institutions. It has encouraged research and learning not only by the number and value of its publications. The publications of the Academy constitute indeed a considerable library and are perhaps only rivalled by the editions of that illustrious national seat of learning, the Academy of Cracow. It has published over two hundred volumes of Memoirs, one hundred volumes of bulletins, a collection of about one hundred volumes of the national writers of Belgium, including the Chronicles of Froissart and Commines and Jehan le Bel. In addition it has published a Dictionary of National Biography of which twenty-two volumes have already appeared, and last but not least, it has issued one hundred and thirty volumes of Belgian Chronicles.

The literary activity of the Academy has been all the more useful because Belgian writers, owing to the exiguity of the national territory, can appeal only to a small audience and are generally depending on the support of the French reading public. That activity has been all the more creditable because hitherto the Belgian Academy has had no legal status and for that reason it cannot administer directly any funds or property which may be left to it.

There are good reasons to hope that in the near future the Belgian Academy will at last be endowed with its civil and legal personality. Under that new regime, under the patronage of an enlightened sovereign, and with a national conscience which has been quickened by the tragedy of the war, the Royal Belgian Academy may look forward to an enlarged sphere of scientific and literary usefulness. The present historical record of the institution may therefore be accepted not only as a fitting tribute to the past, but as the promise of an even more brilliant future.

The Cause and Character of Earthquakes.[1]

By R. D. OLDHAM, F.R.S.

THE stress-difference required to produce fracture in average hard rocks, as they are met with at the surface, is round about 1,000,000 grammes per centimetre square, and, allowing for the greater strength at depth, which is indicated by the experiments of Prof. Adams and the computations of Prof. Barrell, we may put the breaking strength of the earth's crust at about double this quantity, so that to reach this point in one year from starting, the strain would have to increase at the rate of about 1400 grammes per centimetre square in each quarter of a day. According to the late Sir George Darwin the stress-differences set up by the moon in the latitude of Italy would amount to about 20 grammes per centimetre square in an incompressible Earth, and in a compressible Earth with an incompressible crust, a condition much more akin to what we have reason to suppose is the reality, the stress-differences would be many times this figure; but even the lower amount is nearly 1½ per cent. of the growth required to reach breaking point in one year; it would be close on 15 per cent. if the period is increased to ten years, and, with anything approaching this proportion, a periodicity would result which could not have escaped detection before now.

The figures, therefore, give us a lower limit of the rate of growth of strain; it must have been something faster than that needed to reach the breaking point in one year from starting, if the differences on which the argument is based are real. But are they real? The actual amount of difference, barely one per cent. of the mean, is so small that it may well be fortuitous, and the true interpretation may be that the gravitational stresses, and the stress-differences produced by them, have no effect whatever in determining the time of occurrence of an earthquake. If this be so, then the rate of growth of strain becomes infinite, and each earthquake becomes the result of a development of strain, akin to an explosion in its suddenness.

The truth may lie anywhere and must lie somewhere between these extremes, so we reach the conclusion that there is no support for the commonly accepted notion of a continuous, slow growth of strain, extending over years, decades, or even centuries, before the breaking point is reached; on the contrary, it appears that the cause of earthquakes must be a rapid growth of strain. This strain cannot be developed without some deformation, but the magnitude of this has no relation to the frequency or magnitude of the earthquakes; if change of form is slow and prolonged, relief may be provided by gradual yielding, if rapid, a very small amount of distortion may lead to fracture, and on the extent, form, and position of this fracture will depend the character of the resulting earthquake.

This study of the rate of growth leads to the question, which is the really important one in its bearing on geology, of how the strain is produced. It can scarcely be the result of those tectonic processes which result in folding, for these must necessarily be slow in their action; the change of form involved in the bending of solid rock from its original shape into complicated folds, without breach of continuity, can only have been a slow one, and, as we have seen, the deformation which produces earthquakes must be a rapid one. With faults the case is different; many earthquakes are known to have been accompanied by movement along pre-existing fault-places, in others the origin evidently agrees in position with known faults, and in all of these the distribution of the intensity of disturbance is closely correlated with the faults, being greatest in proximity to them and decreasing as the distance becomes greater. So much is indisputable, yet in spite of a general acceptance of the explanation that the earthquake was a result of the same process which gave rise to the formation of the fault, it must be recognised that the proof is not logically complete, for it might be that the cause and process, which gave rise to the earthquake, were wholly different from, and independent of, those which produced the fault, the only connection being that the weakness, resulting from the fault fracture, served to localise the yielding and so controlled the distribution and intensity of the earthquake. In a study of the Californian earthquake of 1906, where the greatest intensity of disturbance ranged along the line of the San Andreas fault, and was accompanied by considerable displacement and distortion of the surface along the fault-line, I was able to show that the earthquake was due to some cause quite distinct from that which produced the fault, and that neither was the fault the cause of the earthquake, nor the earthquake an incident in the formation of the fault.

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[1] Continued from p. 653.

Much more weighty and suggestive evidence is to be derived from some other great earthquakes which have been studied in detail. The conclusion drawn from the Californian earthquake is more fully exemplified by the Indian earthquake of 1897. Here there was no single leading fault and zone of maximum intensity of shock, but a complicated network of lines of extreme destructiveness ramifying over an area not much different in area from that of England, and extending right across a series of great tectonic features, across the great monocline of the southern face of the Assam range, across that range itself, across the alluvial plain of the Brahmaputra Valley, the great boundary faults of the Himalayas, and probably even across the main axis of elevation of the range.

A still more instructive instance is the Charleston earthquake of 1886. There, in a region as devoid of any great structural feature, either of folding or faults, and as little subject to earthquakes, as could be found in our own country, there suddenly occurred a great earthquake, of destructive violence in the central area, and felt over an area measuring about 1500 miles across. It was an earthquake of first-class magnitude, whether we regard the maximum violence of shock, or the extent of area affected, yet there is nothing in the structure of the surface rocks which would suggest its origin being in any tectonic process, and equally nothing which could lead to its classification as volcanic. If we accept the conclusions of Col. Harböe, regarding the character and extent of earthquake origins, the absence of any connexion between the origin of the earthquake and the tectonics of the surface rocks becomes absolute, for, according to this interpretation, the origin becomes almost coextensive with the seismic area, and the diminution of violence in the outer portions is not due solely to enfeeblement, resulting from the elastic propagation of the earthquake wave, but very largely to a diminution in magnitude of the originating impulses.

The interpretation is, I believe, in the main, well founded, and, if it be true that earthquakes of great extent are due to systems of fracture, or analogous disturbance, ramifying over, and practically coextensive with, the seismic areas, of which the dimensions in any direction may be measured in hundreds of miles, it becomes more than ever necessary to recognise that earthquake origins cannot be the result of processes and displacements recorded, and indicated by, the tectonics of the surface rocks. The real and ultimate origin must be more deep-seated, and involve either a displacement of, or a change of volume in, the material underlying the outer crust.

This is no occasion to enter into detail, so I have merely indicated the general character of the studies which have gradually forced me to the conclusion that great earthquakes, and also to a large extent those lesser ones which are commonly classed as tectonic, do not owe their origin to the tectonics of the outer crust, but to processes and changes which take place in the material below it. What these processes may be we cannot know with the certainty which comes from direct observation, for such knowledge as we think we have comes from inference, deduction, and, to some extent, simple assumption, but suggestions have been made which possess a considerable degree of probability. Among these, and especially apposite to present considerations, may be placed Dr. L. L. Fermor's studies of the changes in mineral aggregation which may take place in the solidification of a magma; he has suggested that the determining factor in deciding the form in which the rock finally solidifies is the interrelation of pressure and temperature, and has shown that the change of volume, consequent on the change from one mode to another, may amount to more than 20 per cent. in extreme cases. Mr. W. H. Goodchild has also studied the subject from another point of view, and suggested that some of the changes, especially the separation of metallic sulphides, take place with great, even explosive, rapidity.

It is not improbable that, in the material beneath the outer crust, changes of this character are taking place, some slow and gradual, others more rapid and sudden, but all accompanied by a greater or less change of bulk, either of increase or decrease; and if this be accepted we find an explanation, not only of the forms and origin of earthquakes, but of many other phenomena which are difficult of explanation on any hypothesis of contraction and compression alone. On one hand, slow movements of elevation such as that of the northern Scandinavian region may be attributed to slow and gradual change, involving the whole bulk of large masses; the lesser earthquakes may be due to more rapid changes in smaller portions; the greater to transformation involving a larger bulk of material, and possibly a more abrupt change of combination and density; while the greatest earthquakes, of first-class magnitude, result from similar changes involving still a larger bulk of material and greater change of bulk.

To elaborate these considerations forms no part of my purpose; enough has been said to show that, even in our very fragmentary knowledge of what goes on within the substance of the earth, we have means of explaining and interpreting the greater part of the facts known to us regarding the character of earthquakes. I shall, therefore, conclude by summing up the conclusions which have been put forward as to origin and cause. These are, first, that earthquakes are not due to any slow-acting process of secular duration, but to a rapid development of strain, which may, in extreme cases, be almost instantaneous—a conclusion which I believe to be true of the greater part at least of those usually classed as tectonic, and of all those of great magnitude; and, secondly, that the development of strain is not the result of processes which have produced the tectonic structures, recognised by surface observation, but of changes and displacements in the matter which lies below the cooled and solid outer crust.

Telegraphic Transmission of Photographs.

A NUMBER of experimenters have attained varying measures of success in solving the problem of transmitting photographs, drawings, handwriting, etc., by line and wireless telegraphy, and a good deal of attention has been directed recently to the latest developments of the system on which M. E. Belin has been working in France for some time. His apparatus has been used with good results between the large French wireless station near Bordeaux and a naval station in the United States, as well as over land telephone circuits, etc. A brief description of the latest form of the apparatus appeared in the *Comptes rendus* of the Paris Academy of Sciences of March 6, from which the accompanying illustration is reproduced (Fig. 1).

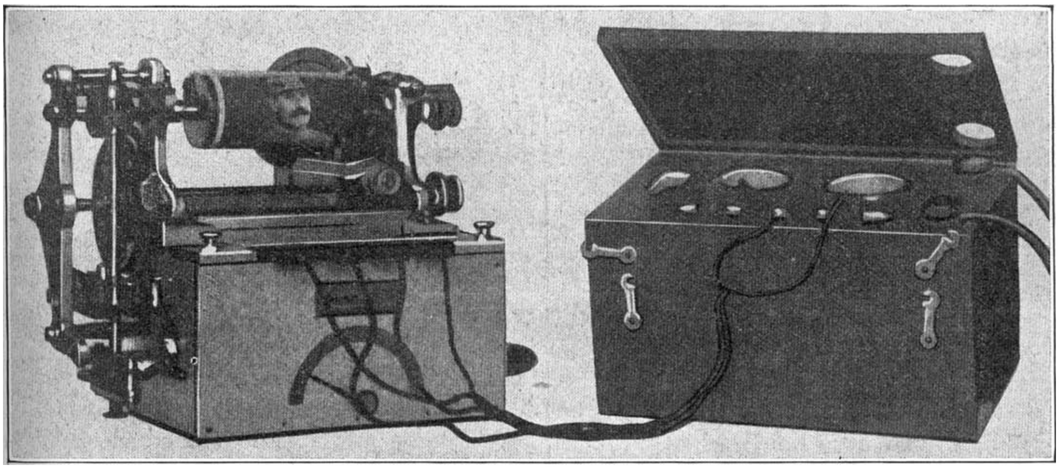

FIG. 1.—Portable apparatus for the telegraphic transmission of photographs.

As in most of the experimental systems of "telephotography," synchronously rotating drums are made use of in the sending and the receiving apparatus respectively, with a simple arrangement of correcting signals to keep them in step. Mounted on the cylinder of the sending apparatus is a print of the photograph to be transmitted, made on a special bichromatised film which gives an image in appreciable relief. It is not necessary, however, to metalise this image to render it conducting, as is necessary in some systems, and it will be seen that the use of selenium cells, which forms a feature in other systems, is also avoided. A stylus, in a holder which is given a slow axial feed, is caused to pass over all portions of the relief film in succession, after the manner of the needle of a phonograph. This stylus is attached to the diaphragm of a simple but sensitive form of carbon granule microphone, included in a suitable circuit, arranged so that a current of varying strength is produced, owing to the variations of the resistance of the microphone according to the thickness of the part of the film that is being passed over. This varying current can either be sent directly over the line, or can be employed to control the strength of the waves sent out, in the case of wireless transmission.

The manner in which the variations in the signal current, or wave train, are retranslated into a photograph by the receiving apparatus is scarcely more complicated. The varying current from the line (or the wireless receiving apparatus) is passed through a delicate reflecting galvanometer such as a Blondel oscillograph, the mirror of which is deflected by an amount depending on the strength of the current, *i.e.* on the thickness of the film where it is being passed over by the stylus of the transmitting apparatus. The light from the mirror passes through a screen of graduated capacity, and the optical system is arranged so that an image of the mirror, varying in brightness according to the deflection, is projected on to a photographic film on the drum, which is moving synchronously with that in the transmitting instrument. The photographic effect produced at any point is therefore always proportional to the thickness of the original film, so that a duplicate photograph formed of a screen of fine lines, but with a full range of "half-tones," is produced. In a simpler form of the apparatus, for pure black and white or "line" work only, a contact-maker replaces the variable resistance microphone in the transmitting apparatus, and a diaphragm, which